



ABRASIVE ARTICLE

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BACKGROUND OF THE INVENTION

5 It is well known that the nature and content of the abrasive grains in a bonded abrasive article have significant influence on the grinding performance of such articles. The term "nature", as herein used, refers to chemical composition, morphology, shape, and size for
10 both the individual abrasive grain and any microcrystalline components thereof. For example, each grit of the sintered sol gel alumina abrasive grains of Cottringer, et al, (U.S. Patent 4,623,364), is composed of an assemblage of alpha alumina crystallites each no
15 larger than 0.4 microns. The sol gel alumina particles of Cottringer are generally described as "seeded".

Other sol-gel alumina abrasive are described in, for example, U.S. Patent 4,314,827 (Leitheiser et al) and U.S. Patent 4,744,802 (Schwabel). Leitheiser et al
20 describes unseeded and Schwabel seeded sol gel alumina abrasives.

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5 It is found that vitreous bonded articles prepared from sol gel alumina abrasive grits may outperform identical articles prepared from conventional fused alumina abrasive by as much as 600% or more in wheel life and in the ratio of metal removed to wheel wear, while consuming less power and removing metal at a higher rate. However, in organic bonded abrasive articles, sintered sol gel abrasives, while superior to normal fused alumina abrasives, have hitherto not shown the dramatic
10 improvement seen in vitreous bonded articles.

At high grinding pressures, organic bonded abrasive articles wear too rapidly to take advantage of the superiority of the individual sol gel alumina grits and at low force levels not enough pressure is exerted on
15 individual grains to microfracture for self-sharpening.

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20 It is well known in the art that dilution of the abrasive grit portion of bonded abrasive articles with softer more friable particles will increase the cutting rate. Hartmann, in U.S. Patent 1,830,757, teaches a self-sharpening wheel in which friable particles of calcined clay, porous alumina, magnesia or glass, all softer than the abrasive grits, are incorporated to break out during grinding leaving an open, free-cutting grinding face. Similarly, Robie, in U.S. patent
25 2,806,772 teaches the use of thin walled balloons, resin micro balloons, porous clay pellets, and other friable particles to provide pore support and increase freedom of cut. Sandmeyer, in U.S. Patent 2,986,850, recognized the unique ability of hollow alumina spheres to serve as both
30 abrasive grit and pore spacer in bonded abrasive articles. Grinding wheels of 100% alumina bubbles, made according to the Sandmeyer patent, wear very rapidly and are only suitable for grinding soft materials such as cork, rubber, fiber board, etc.. Fukada, in U.S. Patent
35 4,226,602, incorporates pore-forming blowing agents with

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or without alumina bubbles in a continuously-formed resin bonded abrasive article of improved cutting ability.

Zimmer, in South African Disclosure 82/0339, describes resin bonded abrasive articles of less than 14%

5 interconnected porosity containing silane-treated porous support material, including alumina bubbles, and multicellular glass modules. The function of the porous materials in this instance was to prevent slumping during cure and reduce infiltration of water during wet
10 grinding.

F Bloecher, U.S. Patent 4,799,939, teaches forming abrasive aggregates particles comprising abrasive particles and glass micro balloons in a phenolic resin bond. These particulate aggregates can then be used to
15 manufacture abrasive products.

Other methods of introducing pores into organic bonded abrasive articles are well known, as exemplified by Pohl, in U.S. Patent 1,986,850 in which uniformly distributed hollow spaces are produced in abrasive bodies
20 by gas evolution and use of soluble or sublimable spheres.

This increase in cutting rate is, however, usually accompanied by a significant increase in the rate at which the abrasive article is worn down. This ratio of
25 the volume of work material removed to volume of abrasive article worn away is known as the "G-ratio". Generally, high G-ratios are clearly preferred but have not hitherto been obtained with conventional abrasive particles.

It has been found that the substitution of friable
30 filler particles such as bubble alumina spheres or softer, more friable, particles for a portion of the sintered sol gel alumina grains not only increases the cutting rate, but decreases the wheel wear for unexpectedly high G-ratios. This is a most unexpected

result and runs counter to the teachings of the prior art.

5 It is, therefore, an object of the present invention to provide an abrasive article in which sintered sol gel alumina abrasive particles are resin bonded and yet provide increased cutting rates with decreased wheel wear.

10 Another object of the invention is to provide an abrasive article offering the advantages of sintered sol gel alumina abrasive particles without unacceptable wheel wear.

15 A further object of the invention is to provide an abrasive article combining excellent cutting rate and acceptable wheel wear characteristics with relatively inexpensive material cost.

Another objective of the invention is to provide an abrasive article which, for a given grinding rate, uses less power and is less likely to damage a workpiece metallurgically.

20 With these and other objectives in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the appended hereto.

SUMMARY OF THE INVENTION

25 In general, the ^{claims} invention relates to an abrasive article comprising sintered sol gel alumina abrasive particles such as those described by Leitheiser, Schwabel, and Cottringer, and friable filler particles, all such particles being bonded in a resinous matrix.

30 In describing the filler particles as friable it is intended to convey that, when the abrasive article is in use and abrasive forces act upon both the abrasive particles and the friable filler particles, the filler particles are worn away significantly more rapidly than
35 are the abrasive particles. Friable filler particles as

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the term is used herein include bubble alumina and other filler particles of about the same or greater friability.

Conveniently, the friable filler particles may be present in an amount of up to about 50%, such as from
5 about 5 to 40%, and preferably from 5 to 30% of the total particle weight. Often this can represent from about 20 to 70% and preferably up to about 50% by volume of the particulate material.

It is preferred that each sintered sol gel alumina
10 abrasive particle be made up of a multitude of sintered alpha alumina crystals having a size in the order of 0.4 micron or finer. The most preferred sol-gel alumina particles are those that have been produced by a seeding technique such as that described in U.S. Patent
15 4,623,364.

The abrasive article may have the form of a wheel or a block or other structure suitable for an abrading use. This is done prior to curing the resinous matrix such that the article has an essentially uniform structure
20 throughout.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The resin bonded abrasive bodies of the invention make use of sintered sol gel alumina abrasive grits together with bubble alumina or other friable filler
25 granules to achieve the fast cutting action well known and expected from such combinations together with an unexpectedly high G-ratio and wheel life. This unexpected combination of properties is of great economic importance since lesser quantities of expensive sol gel
30 alumina abrasive are required to produce high performance grinding wheels and other bonded abrasive bodies.

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The abrasive portion of the ~~invention~~^{inventive} bodies is selected from seeded or unseeded sol gel alumina grits with the seeded variation being particularly preferred. These may be combined with up to about 70% of other abrasives, such as diamond, CBN, sintered or fused alumina, silicon carbide, zirconia, or sintered or fused alumina-zirconia. These abrasives may be surface treated with hydrophobic compounds, such as silanes, where grinding with water-based coolants is anticipated. Such treatments are well-known in the art. All of the abrasives used in the three examples which follow were treated with 0.2cc of silane A1102tm per pound of abrasive and dried at 150°C for 24 hours. Silane A1102tm was obtained from Union Carbide Corporation, Danbury, Connecticut.

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The abrasive particles are often of irregular shape as result of the way in which they are prepared. This is, however, not essential. Spherical, pyramidal, cylindrical (with an aspect ratio, L/D, of for example 0.5 to 10), cubic or any other configuration may be selected. The abrasive particle sizes employed will depend on end use for which the article is intended. However, commonly abrasive particle grit sizes of from about 10 to about 200 and preferably from about 16 to about 120 such as for example from about 20 to about 60 grit are found to be suitable.

The preferable friable filler particles used in the invention are formed from hollow oxide bubbles such as bubble alumina or other hollow silicate particles but may also comprise solid or porous friable particles such as calcined clay, pumice, feldspar, nepheline syenite and the like, as well as solid and hollow spheres made from an organic polymer or glass.

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The friable filler size is preferably the same or less than that of the abrasive particles and, in general, mesh sizes of from 10 to 200 mesh are found to be suitable.

5 A conventional organic resinous binder may be mixed with a variety of additions or modifiers to bind the abrasive grains and friable grains together. Preferably, the organic binder is a thermosetting phenolic resin with or without modifiers such as rubber or epoxy.

10 Examples of resins which may be employed include phenoxy, phenol-furfural, aniline-formaldehyde, urea-formaldehyde, epoxy, cresol-aldehyde, urethane, polyester, polyimides resorcinol-aldehyde, urea-aldehyde, melamine-formaldehyde, and mixtures thereof. The
15 preferred resin bond is a phenolic resin, such as a phenol/formaldehyde resole or novalac.

 As is well known, there are various inorganic and organic adjuvants which may be put in organic bonded abrasive bodies for improving strength, reducing cost,
20 and most importantly for improving grinding performance. The adjuvants are usually considered to be part of the bond and are in a finely divided state, much smaller than the primary grinding abrasive grits.

 Suitable conventional and well known adjuvants
25 include cryolite, fluorspar, iron pyrites, zinc sulfide, magnesia, silicon carbide, sodium chloride, potassium fluoborate, calcium oxide, potassium sulfate, copolymer of vinylidene chloride and vinyl chloride (Saran B), polyvinylidene chloride, polyvinyl chloride, other fibers
30 such as glass fiber, sulfides, chlorides, sulfates, fluorides and mixtures thereof.

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The abrasive articles of the invention are made by forming a mixture of the abrasive particle(s) and the friable filler particles with the resin in its uncured state, and thereafter forming the mixture into the desired shape and curing the resin. It is often, also, desirable to fire the article to drive off volatile material and to harden it. Typically, the shape of the abrasive article will be an abrasive wheel or other abrasive tool.

10 The invention is now further described with reference to the following Examples which are for the purpose of illustration only and are intended to imply no essential limitation to the shape of the invention itself.

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Example 1

A series of nine cold-pressed resin bonded wheel compositions were prepared as follows for grinding tests. The batch compositions are given in Table 1.

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TABLE 1
BATCH WEIGHTS IN POUNDS

Wheel	A(c)	C	D	E	G	J	K
Density	2.54	2.38	2.04	2.17	2.11	2.24	1.82
46 grit size seeded sol-gel alumina abrasive	0	6.33	7.39	11.57	7.14	11.21	13.77
46 grit size fused alumina abrasive	20.11	10.58	0	0	0	0	0
Bubble alumina 0.5-1.0mm dia.	0	0	0	0	0	0	3.60
46 grit size Syenite 333 tm	0	2.99	11.65	7.83	11.27	7.58	0
Varcum 29717 tm powdered phenolic resin	2.30	2.46	2.87	2.70	3.79	3.57	4.25
Varcum 2930 tm liquid phenolic resin	0.37	0.40	0.46	0.44	0	0	0
Cryolite -200 mesh	2.10	2.24	2.62	2.46	2.46	2.32	2.76
Carbon black Chloroflo 40 tm	0.05 50cc	0.05 50cc	0.06 50cc	0.05 50cc	0 40cc	0 0	0 0
Furfural					165cc	156cc	191cc
Quicklime					0.54	0.51	0.61
Iron pyrites.							
Potassium sulfate							

(c) indicates a prior art wheel for comparison.

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Varcum 2930tm Oxy Chem Corporation, Niagara Falls, New York.

5 Varcum 29717tm is a rubber modified powdered phenolic resin available from Varcum Division, Oxy Chem Corporation, Niagara Falls, New York.

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Chloroflo 40tm is a liquid chlorinated paraffin obtainable from Dover Chemical Company, Dover, Ohio.

Standard mixing procedures for the preparation of resin bonded abrasive mixes were followed, i.e., the
10 abrasive and any friable filler particles were placed in a rotating mixing pan and wet with liquid resin or furfural before the introduction of the powdered resin and any adjuvants. After five minutes of mixing the
15 batch was ready to press into wheels. Wheels were pressed to 5 1/8 inch diameter (130.2 mm) with 1 inch (25.4 mm) hole and 0.563 inch (14.3 mm) in thickness using the proper weight of mix to provide the correct final density. In each case this density was calculated to yield 52 volume percent of abrasive or abrasive plus
20 friable filler particles. The wheels were cold pressed. After pressing the wheels were placed on alumina batts and cured in a convection-type electric oven at 175°C for 15 hours. The cured wheels were then finished to 5
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25 inches (127 mm) in diameter and hole was reamed to 1 1/4 inches (31.8 mm) in diameter.

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30 The prepared wheels were then tested in a slot-grinding mode on 4340 steel blocks, hardened to Rc48, 16 1/8 inches (409.6 mm) in length. For this test the face of each wheel was reduced to 1/4 inch in width (6.35 mm) and slots were ground lengthwise into the 4340 steel block using three separate infeeds: 0.5 mils, 1.0 mils and 2.0 mils (0.0126 mm, 0.0254mm and 0.1016 mm). Total depth of infeed for each test was 100 mils (2.54 mm).
35 The test was conducted on a surface grinder with table speed set at 50 feet per minute (15.24 meters per

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5 minute) and wheel speed set at 6500 surface feet per minute (33.02 meters per second). The test was conducted wet using E55tm coolant (available from the White & Bagley Co., Worcester, Massachusetts), diluted with 40 parts of city water. Careful measurements were made of wheel wear and metal removal as well as the power consumed in each slot grind.

The results of the grinding test are given in Table 2 as follows:

TABLE 2
SLOT GRINDING TEST RESULTS

Friable/ Filler	Wheel Marking	Feed (mils)	G Ratio* (S/W)	Relative G Ratio	<i>Power</i> Relative (start/finish)	
					<i>Power</i> Relative (start/finish)	
100% 57A tm fused alumina	A (c)	0.5	13.13	100	100	100
		1.0	5.61	100	100	100
		2.0	2.51	100	100	100
50% 57A tm 30% sol-gel 20% Syenite	C	0.5	50.44	384	71	83
		1.0	13.61	243	83	123
		2.0	4.65	185	96	92
30% sol-gel alumina 70% Syenite	D	0.5	25.53	194	46	88
		1.0	10.96	195	70	100
		2.0	3.38	135	104	81
50% sol-gel alumina 50% Syenite	E	0.5	68.43	521	50	94
		1.0	19.79	353	74	124
		2.0	6.02	240	92	81
30% sol-gel alumina 70% Syenite	G	0.5	67.07	511	50	94
		1.0	14.83	264	78	141
		2.0	3.79	151	92	96
50% sol-gel alumina 50% Syenite	J	0.6	67.69	516	50	100
		1.0	19.66	350	87	112
		2.0	7.55	301	100	96
50% sol-gel alumina 50% bubble alumina	K	0.5	67.59	515	63	106
		1.0	44.99	802	117	153
		2.0	12.81	510	116	92

* "G-Ratio" is the ratio of the volume of metal removed to the volume of wheel worn away in a given period. The relative G-Ratio takes the G-Ratio for a 57a wheel vs 100 and compares the others to that norm.

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57A refers to 57 Alumdumtm which is a fused alumina abrasive and is a product of the Norton Company, Worcester, Massachusetts.

5 Syenite 333tm is a friable mined mineral, nepheline syenite, available from Indusmin Division, Havelock, Ontario, Canada. It is predominantly a vitrified alumina silicate.

All percentages are by volume in the above Table 2.

10 The relative grinding results shown in Table 2 are calculated by dividing the actual value by the value of the standard 57Atm fused alumina wheel A and multiplying by 100. Thus, all relative values for the standard wheel are equal to 100.

15 The preferred invention wheel K, whose abrasive portion is composed of 50% by volume sol-gel alumina and 50% by volume bubble alumina, showed a G-ratio 500 to 800% greater than the standard fused alumina wheel A. Power requirements for wheel K were not excessive; in fact, at the heaviest final downfeed wheel K drew
20 slightly less power than standard wheel A.

25 Wheels C, D, E, G, and J represent another embodiment of the invention in that the diluent for the sol-gel abrasive is a friable silicate particle, in this case, nepheline syenite. From the data in Table 2, the relative G-ratio of these wheels was as much as 516% greater than that of the standard fused alumina wheel A. Wheel J, whose abrasive portion consisted of volume proportions of 50% sol-gel alumina and 50% nepheline syenite, showed a relative G-ratio 516% greater than the
30 standard at the lowest infeed and 300% greater than the standard at the highest infeed without an increase in power.

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Example 2

A series of six test wheels of the same size as those in Example 1 were prepared from the batch compositions shown in Table 3.

TABLE 3
BATCH WEIGHTS IN POUNDS

Wheel marking	1(c)	2(c)	3(c)	4	5
Density	2.54	2.61	2.6	1.83	1.82
46 grit size seeded sol-gel alumina abrasive	0	0	3.48	4.94	8.27
46 grit size fused alumina abrasive	12.14	11.18	8.31	3.36	0
Bubble alumina 0.5-10mm dia.	0	0	0	2.16	2.16
Varcum 29717 tm powdered phenolic resin	1.39	1.79	1.85	2.62	2.63
Varcum 2930 tm liquid phenolic resin	0.22	0	0	0	0
Cryolite -200 mesh	1.27	1.16	1.20	1.70	1.71
Chloroflo 40 tm Furfural	23cc	24cc 80cc	24cc 81cc	24cc 114cc	24cc 115cc
Quicklime		0.26	0.26	0.38	0.38

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Methods of mixing, cold pressing and curing were the same as in Example 1. After finishing to size these test wheels were subjected to the same slot grinding test as in Example 1 with the exception that horsepower was measured by dynamometer. The results of grinding these are shown in Table 4.

TABLE 4
SLOT GRINDING TEST RESULTS

Abrasive/ Friable Filler	Wheel Marking	Feed (mils)	G Ratio (S/W)	Relative G Ratio	Relative Power
100% 57A tm fused alumina	1(c)	0.5	15.37	100	100
		1.0	6.37	100	100
		2.0	3.10	100	100
100% 57A tm fused alumina	2(c)	0.5	18.02	117	192
		1.0	9.32	146	125
		2.0	5.00	161	137
70% 57A tm fused alumina 30% sol-gel alumina	3(c)	0.5	30.85	201	149
		1.0	16.25	255	125
		2.0	4.80	155	93
20% 57A tm fused alumina 30% sol-gel alumina 50% bubble Alumina	4	0.5	50.13	326	113
		1.0	21.70	341	91
		2.0	6.43	207	84
50% sol-gel alumina 50% bubble alumina	5	0.5	81.01	527	72
		1.0	38.46	604	80
		2.0	16.75	540	87

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All percentages given by volume.

Wheels 1, 2 and 3 are for comparative purposes.

The test results of Example 2 as shown in Table 4 again illustrate the marked increase in G-ratio of the preferred invention wheels. Both wheels 3(c) and 4 contain 30% sintered sol-gel alumina abrasive by volume of total abrasive; however, the remainder of the abrasive portion of wheel 3 is 70% fused alumina. Wheel 4, containing 50% bubble alumina, considerably outperforms wheel 3 in both G-ratio and power even though both contain the same volume (30%) of sintered sol-gel alumina. Wheel 5, whose abrasive portion is 50% sintered sol-gel alumina and which contains 50% bubble alumina, outperformed the standard fused alumina wheel by 527 to 604% in G-ratio and drew 13% to 27% less power.

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Example 3

In this series of test wheels, various blends of sintered sol-gel alumina with fused alumina and bubble alumina were evaluated. The compositions of the mix batches from which these wheels were pressed are given in Table 5.

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TABLE 5
BATCH WEIGHTS IN POUNDS

Wheel marking	6	7	8	9	10	11
Density	2.37	2.02	2.01	2.00	2.09	2.00
46 grit sol-gel alumina	1.69	1.99	5.99	10.03	9.63	10.03
46 grit 57A tm fused alumina	12.13	8.14	4.86	0	0	0
0.5mm-1mm bubble alumina	1.49	4.38	4.40	4.42	4.24	4.42
Varcum 29717 tm powdered phenolic resin	2.70	2.90	3.19	3.20	3.06	3.20
Cryolite -200 mesh	1.75	1.88	2.06	2.07	0	2.07
Iron pyrites	0	0	0	0	2.39	0
Potassium sulfate	0	0	0	0	0.45	0
Chloroflo 40 tm	32cc	32cc	32cc	32cc	32cc	32cc
Furfural	118cc	126cc	139cc	139cc	154cc	139cc
Quicklime	0.39	0.42	0.46	0.46	0.44	0.46

Methods of mixing, cold pressing and curing were the same as in Example 1. After finishing to size these test wheels were subjected to the same slot grinding test as in Example 1 with the exception that horsepower was measured by dynamometer. The results of the grinding test are shown in Table 6.

TABLE 6
SLOT GRINDING TEST RESULTS

Abrasive/ Friable Filler	Wheel Marking	Feed (mils)	G Ratio (S/W)	Relative G. Ratio	Relative Power
70% 57A tm fused alumina	6	0.5	22.79	148	105
10% sol-gel alumina		1.0	11.49	180	93
20% bubble alumina		2.0	2.44	79	89
40% 57A tm fused alumina	7	0.5	26.40	172	92
10% sol-gel alumina		1.0	10.70	168	91
50% bubble alumina		2.0	3.86	124	75
20% 57A tm fused alumina	8	0.5	65.58	427	73
30% sol-gel alumina		1.0	22.67	356	79
50% bubble alumina		2.0	5.14	166	63
50% sol-gel alumina	9	0.5	107.47	699	57
50% bubble alumina		1.0	48.93	768	77
(cryolite filler)		2.0	8.54	275	65
50% sol-gel alumina	10	0.5	91.49	595	60
50% bubble alumina		1.0	45.31	711	74
(iron pyrites + K ₂ SO ₄ fillers)		2.0	9.92	320	69
50% sol-gel alumina	11	0.5	67.01	436	59
50% bubble alumina		1.0	45.49	714	69
(both silane treated)					

All percentages are by volume.

The grinding test results from Example 3 again show the unexpectedly large increase in G-ratio obtained from combinations of sintered sol-gel alumina and alumina

5 bubbles and other embodiments of the invention. Wheels 9, 10, and 11 which contain 50% sintered sol-gel alumina and 50% alumina bubbles by volume of the abrasive portion gave G-ratios 275% to 768% greater than a standard wheel containing 100% fused alumina. The power expended in grinding was 25% to 40% less for the invention wheel indicating that the invention wheel is much more efficient and would be less likely to cause metallurgical damage to the workpiece.

Example 4

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The following results were obtained in a commercial [hot mill roll] grinding [operation]. The rolls were [of high chromeiron and the grinding was done] at essentially constant full power. The results obtained are set forth in Table 7 below.

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TABLE 7

Wheel	Abrasive*	Total Metal Remove (in.)	Relative G Ratio	Metal Removal Rate	Comments
12	50% 57A tm 50% Black SiC	1.7	100%	100%	Chatter
13	20% Sol-Gel Alumina 80% Green SiC	4.1	240%	125%	No Chatter
14	20% Sol Gel Alumina 60% Green Sic 20% Bubble Alumina	5.2	310%	250%	No Chatter

*Percentages are by volume of total particulate (abrasive and friable filler) in the wheel.

By replacing 20% of SiC (silicon carbide) with bubble alumina (Wheel 14 compared to Wheel 13) resulted in a large improvement in both Metal Removal Rate and G Ratio. This is a highly unusual result because, normally, improvements in G Ratio are gained at the expense of metal removal rate - and vice versa.

The embodiments disclosed herein are illustrative of the unexpectedly high G-ratios obtainable when hollow oxide spheres or friable particles are incorporated into abrasive bodies whose abrasive portion is wholly or in part composed of sintered sol-gel alumina grits and such embodiments are not in any way limiting.

Obviously minor changes may be made in the form and construction of this invention without departing from its spirit. Thus, it is not desired to confine the invention to the exact form shown and described, but it is desired to include all such as properly come within the scope claimed.

We claim:

Example 5

This example shows a hot mill grinding of a high chrome iron roll. The grinding was carried out in a commercial plant at essentially full power level. The results are set forth in Table 8 below.

TABLE 8

<u>Wheel</u>	<u>Vo. % Composition</u>	<u>Total of Steel Removed (inches)</u>	<u>Rel. G-Ratio</u>	<u>Comments</u>
15	57A - 50% 37C - 50%	1.7	100%	Chattering
16	SG - 20% 39C - 80%	4.1	240%	No chatter
17	SG - 20% 39C - 60% BA - 20%	5.2	310%	No chatter

SG = Seeded Sol-Gel alumina
 37C = Black silicon carbide
 39C = Green silicon carbide
 BA = Bubble alumina

The invention having been thus described, what is claimed as new and desired to secure by Letters Patent is: